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ATTORNEY'S DOCKET NO. **970054.412USPC**

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

U.S. APPLICATION NO. (If known, see37 CFR 1.5) Unknown 10/031840

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP00/02417	**18 March 2000 (18.03.00)**	**20 July 1999 (20.07.99)**

TITLE OF INVENTION

METHOD AND DEVICE FOR DESALTING WATER

APPLICANT(S) FOR DO/EO/US

WOBBEN, Aloys

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   b. ☒ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is attached hereto
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☒ A English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☒ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 – 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4)
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☐ Other items of information:

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U.S. APPLICATION NO. (If known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
Unknown 10/031840	**PCT/EP00/02417**	**970054.412USPC**

21. ☒ The following fees are submitted:

Basic National Fee (37 CFR 1.492(a)(1)-(5)):

CALCULATIONS
PTO USE ONLY

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO $1040.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO $890.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO $740.00

International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)..................... $710.00

International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) $100.00

ENTER APPROPRIATE BASIC FEE AMOUNT =				$890.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☒ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$130.00	
Claims	Number Filed	Number Extra	Rate		
Total Claims	11 - 20 =	0	x $ 18.00	$0.00	
Independent Claims	2 - 3 =	0	x $ 84.00	$0.00	
Multiple dependent claim(s) (if applicable)			+ $280.00	$.00	
TOTAL OF ABOVE CALCULATIONS =				$1,020.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				$.00	
SUBTOTAL =				$1,020.00	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$.00	
TOTAL NATIONAL FEE =				$.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$.00	
TOTAL FEES ENCLOSED =				**$1,020.00**	
				Amount to be refunded:	
				charged	

a. ☒ A check in the amount of $1,020.00 cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. in the amount of $_ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **19-1090**. A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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31,153
REGISTRATION NUMBER

10/031840

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PATENT COOPERATION TREATY

Int'l Application No.	:	PCT/EP00/02417
Int'l Filing Date	:	18 March 2000
U.S. Application No.	:	Not yet known
Inventors	:	WOBBEN, Aloys
Title	:	METHOD AND DEVICE FOR DESALTING WATER
Docket No.	:	970054.412USPC
Date	:	22 January 2002

Box PCT
Assistant Commissioner for Patents
Washington, DC 20231-0001

PRELIMINARY AMENDMENT

Sir:

Please enter a Preliminary Amendment by replacing the application and claims presently on file as identified above with the enclosed substitute specification and claims prior to examination on the merits.

Respectfully submitted,

Seed Intellectual Property Law Group PLLC

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Method and device for desalting water

The invention concerns a method for desalting water by reverse osmosis according to the preamble of claim 1, as well as a device for the implementation of that method.

A method and device of this type are known from WO 97/21483. Here, the salt water is pressurized by applying an exterior pressure to a pressure medium, the pressure of which is then transferred to the salt water. The design of one embodiment is such, that the salt water at first is pumped by a first pump into a first chamber of a three-chamber configuration at relatively low pressure. Subsequently, a high-pressure pump applies a high pressure to a pressure medium in a second chamber of the three-chamber configuration, which results in the saltwater in the first chamber to be conveyed into the membrane module at the high pressure necessary for reverse osmosis. Simultaneously, the concentrated salt water, which has not penetrated through the membrane of the membrane module, is conveyed into a third chamber of the three-chamber configuration Finally, the next delivery of salt water by the first pump into the first chamber results in the concentrated salt water being discharged from the third chamber, and ultimately from the device

In this known method the high-pressure pump delivers a pressure medium at a high pressure level to the membrane modules, and no longer has to pump salt water, as has been the case in other known methods, and which due to the salt water's oxidation potential exacted high demands on the material of the pump, which significantly increased its costs But a high-pressure pump to create the pressure necessary for reverse osmosis is still required, which has a negative effect on the energy balance, and consequently on the overall efficiency of the device. In addition, the known method operates in two processing steps, whereby one of the two processing steps generates desalted water, while the other processing step re-supplies salt water and discharges the concentrated salt water.

The object of the invention is to provide a method with improved efficiency and a device for the implementation of that method.

Starting with the above-mentioned method and the above-mentioned device, this problem is solved by the method according to claim 1 and the device according to claim 7

The invention is based on the realization that a pump to generate the high pressure necessary for reverse osmosis can be omitted entirely and be replaced by a pump generating a significantly lower pressure, if the pressure, which the concentrated salt water inevitably possesses at the outlet of the membrane module, can be utilized by continuously re-circulating this concentrated salt water into the pressure-compensating device to pressurize the salt water pumped into the pressure-compensating device. In this context it is especially important that this process takes place continuously, since otherwise the pressure in the salt water feed pipe from the pressure-compensating device to the membrane module would drop and would have to be re-generated by a high-pressure pump. as is the case in the known method, and in addition no continuous production of desalted water would be possible.

Advantageous further developments of the method and the device follow from the dependent claims

The invention is explained in more detail in the following with the help of the figures.

Fig. 1 shows a schematic diagram illustrating the method according to the invention,

Fig. 2 shows an embodiment of the device according to the invention,

Figs. 3a, b show representations of this embodiment during different operating stages, and

Fig. 4 is a representation of the operating stages of this embodiment during a complete operating cycle.

The schematic diagram of Fig. 1 shows a feed pump 1 to introduce salt water 10 into a pressure-compensating device 2 at a first pressure p_1. The same salt water 11, which now is pressurized to the high operating pressure necessary for reverse osmosis, is conveyed from the pressure-compensating device 2 to the membrane module 3. Here part of the salt water 11, due to the high pressure, penetrates though the membrane 6 (for example 25% of the salt water 11), is desalted in the process, and is discharged as desalted water 12 The remaining portion of the salt water 11 (e.g. 75%) cannot penetrate through the membrane 6, and is returned as concentrated salt water 13, still at the high pressure level $p_{2,}$ to the pressure-compensating device 2 through a connecting line 5. There, this high pressure level is used, in a manner still to be explained in more detail, to pressurize the salt water 10 introduced into the pressure-compensating device 2 to a high pressure level and to convey it to the intake of the membrane module 3. Simultaneously, also in a manner still to be explained in more detail, the pressure level p_1, to which the salt water 10 is pressurized by the feed pump 1, is used in the pressure-compensating device 2 to ultimately discharge any concentrated salt water 14 present therein through the discharge line 4 All of the described stages take place simultaneously and continuously, so that no high-pressure pump is required to re-generate a high operating pressure, and desalted water 12 is available continuously.

In particular the design and operating principle of the pressure-compensating device 2 will be explained in more detail with help of the invention's embodiment shown in Fig 2 Here, the pressure-compensating device possesses three identical piston devices 20, 30, 40, each of which possesses one intake chamber 21, 31, 41 to take in the salt water 10, one discharge chamber 22, 32, 42 to accept the concentrated salt water 13, and one pressure chamber 23, 33, 43

Each of the piston devices 20, 30, 40 contains a special piston 24, 34, 44, which subdivides the piston interior into the mentioned chambers, and which in the drawing can move in the vertical direction within the piston arrangement. Feed pipes with (passive) check valves 28, 38, 48 lead from the feed pump 1 to each of the intake chambers 21, 31, 41. Hereby, the design of the check valves 28, 38, 48 is such that they open to admit flow if the pressure level in the feed pipe is higher than that in the intake chambers 21, 31, 41. The feed pipes from the intake chambers 21, 31, 41 to the membrane module 3 also contain check valves 27, 37, 47 of this type, but with a different flow direction. In contrast, the feed pipe 5 from the membrane module to the discharge chambers 22, 32, 42, and the discharge line 4 from the discharge chambers 22, 32, 42, are provided with actively controlled valves 25, 35, 45, and 26, 36, 46, respectively, which may be used to regulate the inflow of concentrated salt water 13 from the membrane module 3, or the outflow of the concentrated salt water 14 from the pressure-compensating device 2. The pressure chambers 23, 33, 43 are connected to each other by a connecting line 7, in order to enable pressure compensation between these three chambers and to ensure an identical pressure level p_3 in all three chambers.

The following illustrates the operating principle of the device: The feed pump 1 pumps 100% of the required volume of salt water 10 at a first pressure p_1 level (e.g 17 5 bar) into the intake chamber 31, whereby the check valve 38 opens, which is indicated by the arrow next to it At this time the valve 36 is open (indicated by the arrow next to it), so that the concentrated salt water 14 present in the discharge chamber 32 can be discharged through the discharge line 4. As a result of the salt water 10 flowing into the intake chamber 31 at a pressure level p_1, the piston 34 is subjected to a force $F = p_1 \cdot A$, where A is the surface area of the piston face 341. As a result, the piston 34 is pushed upward, as indicated in the figure, and the concentrated salt water present in the discharge chamber 32 is discharged through the valve 36 and the discharge line 4. The pressure level p_3 prevailing in the pressure chamber 33 gives rise to an opposing force $F_G = p_3 \cdot A_G$ (A_G is the surface area of the part 343 of the rear of the piston, e.g. a quarter of the piston's rear side), which is nearly as large, or slightly smaller than the force F. During the same shown operating stage, the valve 25 is open, so that the concentrated salt water 13 flows from the membrane module 3 into the discharge chamber 22 at the pressure level p_2 (e g 70 bar)

Simultaneously, in the pressure chamber 23, which has been filled by the pressure medium through the connecting line 7 due to the upward travel of the piston 34, a force is exerted on the piston 24, causing it to travel downward, as indicated by the arrow. This causes the salt water 11 to be conveyed from the intake chamber 21 through the open check valve 27 to the membrane module 3. Inevitably, this takes place at the pressure level p_2 (70 bar), since the discharge chamber 22 and the pressure chamber 23 are subjected to a pressure of that level. All other valves are closed during the shown operating stage.

Consequently, the shown embodiment of the pressure-compensating device 2 achieves a pressure transformation, which allows a highly efficient energy recovery from the concentrated salt water 13 being discharged. For this reason, instead of a high-pressure pump to generate the high operating pressure necessary for reverse osmosis one only requires a low-power filling pump 1, which in this particular case only has to generate a pressure level that is one quarter of the working pressure.

Figs 3a and 3b show six different successive operating stages of the device according to the invention. Hereby the arrows 201, 202, 301, 302 are meant to indicate an open valve and the direction of the flow. The arrows 203, 303, and the zero 403 are meant to show whether the piston of the respective piston device 20, 30, 40 is moving, and if so, the direction of its travel. Position sensors 204, 205, 304, 305 to detect the piston position are provided at each of the upper and lower ends of the pressure chambers 23, 33, 43 of the piston devices 20, 30, 40. The left-hand diagram of each of the stage diagrams shows the valve position and piston travel direction that were in effect to reach the shown piston position. The right-hand diagram of each stage diagram then shows how from this point in time the pistons will move as a result of the changed valve settings For example, the left-hand diagram of the representation of stage 1 shows that up to that moment the piston 24 has been traveling downward to the limit stop (arrow 203), that the piston 34 is in the process of traveling upwards (arrow 303), and that the piston 44 was remaining at an upper limit position (zero 403). After switching the valves – valve 25 has been closed and valve 45 has been opened; valve 27 closes whereupon valve 47 opens automatically – the piston 24 remains in its lower limit position, as shown in the right-hand diagram of the representation of stage 1, while the piston 34 continues to travel upward and the piston 44 is traveling downward. The last stage 6 is again followed by stage 1.

The following table illustrates the valve settings in the six shown stages, whereby '+' represents an open valve and '-' represents a closed valve.

Stage Valve	1	2	3	4	5	6
25	+	-	-	-	-	+
26	-	-	+	+	-	-
35	-	-	-	+	+	-
36	+	+	-	-	-	-
45	-	+	+	-	-	-
46	-	-	-	-	+	+
27	+	-	-	-	-	+
28	-	-	+	+	-	-
37	-	-	-	+	+	-
38	+	+	-	-	-	-
47	-	+	+	-	-	-
48	-	-	-	-	+	+

Finally, Fig 4 shows the operating states, i.e. the piston positions over the course of a complete operating cycle, which here has been subdivided into twelve individual stages. Once again, the direction of the arrow represents the direction of travel of the respective piston.

The invention is not restricted to the shown embodiment; in particular the pressure-compensating device can be of a different design. Alternative designs are possible, for example configurations with only two piston devices, or more than three piston devices, and/or piston devices that are of different designs or are different from each other. Furthermore, the specified numerical values are only examples used to illustrate the invention, i e a modified piston geometry can result in different pressure ratios, for example

The method and device according to the invention make it possible to achieve a very high energy-recovery efficiency of at least 90%. The feed pump only has to generate approximately a quarter of the working pressure of approximately 70 bar necessary for reverse osmosis, which entails significant cost-reduction- and service benefits. Consequently, the invention significantly reduces the general manufacturing costs of a device to desalt water and provide drinking water. The specified pressure ratio (17.5 bar: 70 bar) can be fixed at a different ratio. This can be accomplished by modifying the piston geometry. The piston geometry is not limited to a single possible configuration. Depending on the salt content of the water, the osmotic pressure can and should be adapted. A lower pressure can be selected for brackish water, which has the lowest salt content; in this case the ratio may be changed or adjusted from 1/4: 3/4 to 1/3: 2/3.

The pressure in the pressure chambers 23, 33, 43 is established during start-up of the device and subsequently is kept constant at that level.

Claims

1. Method to desalt water by reverse osmosis, in particular to desalt sea water, in which salt water (10) at a first pressure level (p_1) is introduced into a pressure-compensating device (2), and from the pressure-compensating device (2) is conveyed at a second higher pressure level (p_2) into a membrane module (3), whereby desalted water (12) and concentrated salt water (13) are discharged from the membrane module (3),
characterized in that the concentrated salt water (13) being discharged from the membrane module (3) is continuously introduced at a second pressure level (p_2) into the pressure-compensating device (2), where it is used to pressurize the salt water (10), which has been introduced into the pressure-compensating device (2), to the second pressure level (p_2), and to carry off salt water (11) to the membrane module (3).

2 Method according to claim 1,
characterized in that from the membrane module (3) the concentrated salt water (13) is conveyed at the second pressure level (p_2) into a discharge chamber (22, 32, 42) of one of several piston devices (20, 30, 40), where it acts upon the piston (24, 34, 44) in such a manner that the salt water (10), which has been introduced into an intake chamber (21, 31, 41) of the same piston device (20, 30, 40), is conveyed at the second pressure level (p_2) into the membrane module (3)

3. Method according to claim 2,
characterized in that the concentrated salt water (13) is introduced alternately into the discharge chamber (22, 32, 42) of one of the several piston devices (20, 30, 40), whereby simultaneously the salt water (11) is conveyed from the intake chamber (21, 31, 41) of the same piston device (20, 30, 40) into the membrane module (3), and in that simultaneously salt water (10) at the first pressure level (p_1) is introduced into the intake chamber (21, 31, 41) of a different piston device (20, 30, 40), whereby the concentrated salt water (14) is discharged from the discharge chamber (22, 32, 42) of the same piston device (20, 30, 40) at a low pressure level.

4. Method according to claim 3,
characterized in that the piston devices (20. 30, 40) of the pressure-compensating device (2) are controlled in such a manner that simultaneously salt water (10) is introduced into the intake chamber (21, 31, 41) of at least one piston device (20, 30, 40), concentrated salt water (14) is discharged from the discharge chamber (22, 32, 42) of the same piston device (20, 30, 40), concentrated salt water (13) is introduced into the discharge chamber (22, 32, 42) of at least one other piston device (20. 30, 40), and salt water (11) from the intake chamber (21, 31, 41) of the same piston device (20, 30, 40) is conveyed to the membrane device (3).

5. Method according to claim 4,
characterized in that the piston devices are regulated by controllable intake- and discharge valves (25 – 28, 35 – 38, 45 – 48).

6. Method according to one of claims 2 to 5.
characterized in that each of the employed piston devices (20, 30, 40) contains one intake chamber (21, 31, 41), one discharge chamber (22, 32, 42), and one pressure chamber (23, 33, 43), and in that the pressure chambers (23, 33, 43) of the piston devices (20, 30, 40) are connected to each other and exert a continuous pressure (p_3) on a part (343) of the piston (34) for the purpose of assisting the pressure (p_2), which is exerted upon the piston by the concentrated salt water (13) introduced into the discharge chamber (22, 32, 42)

7 Device for the implementation of the method according to one of the preceding claims, with a feed pump (1) to introduce salt water (10) into the pressure-compensating device (2) and with a membrane module (3) to separate salt water (11) introduced from the pressure-compensating device (2) into desalted water (12) and concentrated salt water (13),
characterized in that between the membrane module (3) and the pressure-compensating device (2) is provided a connecting line (4), which during operation is continuously pressurized to the second pressure level (p_2), and serves in feeding the concentrated salt water (13) from the membrane module (3) to the pressure-compensating device (2) and in feeding the salt water (11) from the pressure-compensating device (2) to the membrane module (3).

8 Device according to claim 7,
characterized in that the pressure-compensating device (2) contains several piston devices (20, 30, 40), each of which contains an intake chamber (21, 31, 41) connected to the membrane module (3) and the membrane module (3), each of which further contains a discharge chamber (23, 33, 43) connected to the membrane module (3) and to a discharge line (4) for the concentrated salt water (14), and each of which further contains a pressure chamber (23, 33, 43), whereby the pressure chambers (23, 33, 43) of the piston devices (20, 30, 40) are connected to each other and are continuously pressurized to the pressure level (p_3).

9. Device according to claim 8,
characterized in that the piston devices (20, 30, 40) are controlled in such a manner that simultaneously salt water (10) is introduced into the intake chamber (21, 31, 41) of at least one piston device (20, 30, 40), concentrated salt water (14) is discharged from the discharge chamber (22, 32, 42) of the same piston device (20, 30, 40), concentrated salt water (13) is introduced into the discharge chamber (22, 32, 42) of at least one other piston device (20, 30, 40), and salt water (11) is conveyed from the intake chamber (21, 31, 41) of the same piston device (20, 30, 40) to the membrane device (3)

10 Device according to claim 9,
characterized in that the piston devices (20, 30, 40) are regulated by controllable intake- and discharge valves (25 – 28, 35 – 38, 45- 48)

11 Device according to claim 10,
characterized in that the connecting lines (5) from the membrane module (3) to the discharge chambers (22, 32, 42) of the piston devices (20, 30, 40) and the lines (4) to discharge concentrated salt water (14) from the discharge chambers (22, 32, 42) contain actively controlled valves (25, 26, 35, 36. 45, 46)

12 Device according to one of claims 7 to 11,
characterized in that the pressure-compensating device (2) contains three identical piston devices (20, 30, 40)

13 Device according to one of claims 8 to 12,
characterized in that the pistons (24, 34, 44) of the piston devices (20, 30, 40) are designed in such a manner that the pressure level (p_3) prevailing in the pressure chamber (23, 33, 43) can act upon one quarter of the surface area of the rear side of the piston (343) and the pressure prevailing in the discharge chamber (22, 32, 42) can act upon three quarters of the surface area of the rear side of the piston (342).

Abstract

The invention concerns a method for desalting water by reverse osmosis, in particular for desalting sea water, whereby salt water at a first pressure level is introduced into a pressure compensating device, and is conveyed from the pressure-compensating device at a second, higher pressure level into a membrane module, whereby desalted water and concentrated salt water are discharged from the membrane module. In order to increase the efficiency and consequently the energy balance of such a method, the invention proposes to continuously introduce the concentrated salt water, which has been discharged from the membrane module, at a second pressure level into the pressure-compensating device, wherein it is used to subject the salt water introduced into the pressure compensating device to the second pressure level, and to discharge the salt water and convey it to the membrane module The invention also concerns a device for implementing this method.

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/Translation of letter head information omitted (The Translator)/

Bremen, April 9, 2001

Our reference: W 2075 KGG/STK/ml/sin

Applicant/Patentee: ALOYS WOBBEN
Official file ref.: PCT/EP00/02417

New claims 1 to 10

1 Method for the continuous desalting of water, in particular for the desalting of sea water, whereby

- salt water (11) is introduced into a membrane module (3) and is separated into desalted water (12) and concentrated salt water (13),
- the salt water (11) is conveyed at an increased pressure level (p_2) from the pressure-compensating device (2), which comprises several piston devices (20, 30, 40), to the membrane module (3),
- the concentrated salt water (13) is discharged from the pressure-compensating device (2), transferring its pressure energy in the process,
- salt water (10) is introduced into the pressure-compensating device 2 at a pressure level (p_1) by means of a feed pump (1),
- in front of the piston, the piston devices (20, 30, 40) contain an intake chamber (21, 31, 41), which is connected to the feed pump (1) and the membrane module (3), and in the rear of the piston they contain a discharge chamber (22, 32, 42), which is connected to the membrane module (3) and a discharge line (4) for concentrated salt water (14),

characterized in that, during operation a continuous pressure (p_3) is exerted on a part (343) of the piston (24, 34, 44) by means of a hydraulic connection between the pressure chambers (23, 33, 43), which are located at the piston rear sides of the piston devices (20, 30, 40), to assist the pressure level (p_2), which is exerted on the piston (24, 34, 44) by the concentrated salt water (13) that has been introduced into the discharge chambers (22, 34, 44)

2. Method according to claim 1,
characterized in that the concentrated salt water (13) alternately is introduced into the discharge chamber (22, 32, 42) of one of several piston devices (20, 30, 40), whereby simultaneously the salt water (11) is conveyed from the intake chamber (21, 31, 41) of the same piston device (20, 30, 40) to the membrane module (3), and in that simultaneously salt water (10) at a first pressure level (p_1) is introduced into the intake chamber (21, 31, 41) of a different piston device (20, 30, 40), whereby the concentrated salt water (14) is discharged at a low pressure level from the discharge chamber (22, 32, 42) of the same piston device (20, 30, 40).

3. Method according to claim 2,
characterized in that the piston devices (20, 30, 40) of the pressure-compensating device (2) are controlled in such a manner that simultaneously salt water (10) is introduced into the intake chamber (21, 31, 41) of at least one of the piston devices (20, 30, 40), concentrated salt water (14) is discharged from the discharge chamber (22, 32, 42) of the same piston device (20, 30, 40), concentrated salt water (13) is introduced into the discharge chamber (22, 32, 42) of at least one other piston device (20, 30, 40), and salt water (11) is conveyed from the intake chamber (21, 31, 41) of the same piston device (20, 30, 40) into the membrane device (3)

4 Method according to claim 3,
characterized in that the piston devices (20, 30, 40) are regulated by controllable intake- and discharge valves (25 – 28, 35 – 38, 45 – 48)

5. Reverse osmosis device for the continuous desalting of water, in particular for the desalting of sea water,
- with a membrane module (3) to separate supplied salt water (11) into desalted water (12) and concentrated salt water (13),
- with a pressure-compensating device (2), comprising several piston devices (20, 30, 40), to continuously introduce the salt water (11) at an increased pressure level (p_2) into the membrane module (3) and to discharge the concentrated salt water (13), transferring its pressure energy in the process,
- with a feed pump (1) to introduce salt water (10) at a pressure level (p_1) into the pressure-compensating device (2), whereby

- in front of the piston, the piston devices (20, 30, 40) possess an intake chamber (21, 31, 41), which is connected to the feed pump (1) and the membrane module (3), and
- in the rear of the piston, the piston devices (20, 30, 40) possess a discharge chamber (22, 32, 42), which is connected to the membrane module (3) and to a discharge line (4) for concentrated salt water (14),

characterized in that

- in the rear of the piston, the piston devices (20, 30, 40) additionally possess a pressure chamber (23, 33, 43) and the pressure chambers are hydraulically connected to each other, so that during operation a continuous pressure (p_3) can be exerted on a part (343) of the piston (24, 34, 44) to assist the pressure (p_2), which is exerted on the piston (24, 34, 44) by the concentrated salt water (13) introduced into the discharge chamber (22, 32, 42).

6. Device according to claim 5,
characterized in that the piston devices (20, 30, 40) are controlled in such a manner that simultaneously salt water (10) is introduced into the intake chamber (21, 31, 41) of at least one piston device (20, 30, 40), concentrated salt water (14) is discharged from the discharge chamber (22, 32, 42) of the same piston device (20, 30, 40), concentrated salt water (13) is introduced into the discharge chamber (22, 32, 42) of at least one other piston device (20, 30, 40), and salt water (11) is conveyed from the intake chamber (21, 31, 41) of the same piston device (20, 30, 40) to the membrane module (3)

7 Device according to claim 6,
characterized in that the piston devices (20, 30, 40) are regulated by controllable intake- and discharge valves (25 – 28, 35 – 38, 45 – 48)

8. Device according to claim 7,
characterized in that the connecting lines (5) from the membrane module (3) to the discharge chambers (22, 32, 42) of the piston devices (20, 30, 40), and the lines (4) to discharge concentrated salt water (14) from the discharge chambers (22, 32, 42) are provided with actively controlled valves (25, 26, 35, 36, 45, 46)

9 Device according to one of claims 5 to 8,
characterized in that the pressure-compensating device (2) contains three identical piston devices (20, 30, 40).

10. Device according to one of claims 5 to 9, characterized in that the pistons (24, 34, 44) of the piston devices (20, 30, 40) are designed in such a manner that the pressure level (p_3) prevailing in the pressure chamber (23, 33, 43) can act upon one quarter of the surface area of the piston rear side (343) and the pressure level prevailing in the discharge chamber (22, 32, 42) can act upon three quarters of the surface area of the piston rear side (342).

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METHOD AND DEVICE FOR DESALTING WATER

BACKGROUND OF THE INVENTION

Field of the Invention

The invention concerns a method for desalting water by reverse osmosis, as well as a device for the implementation of that method.

Description of the Related Art

A method and device for desalting water are known from WO 97/21483. Here, the salt water is pressurized by applying an exterior pressure to a pressure medium, the pressure of which is then transferred to the salt water. The design of one embodiment is such, that the salt water at first is pumped by a first pump into a first chamber of a three-chamber configuration at relatively low pressure. Subsequently, a high-pressure pump applies a high pressure to a pressure medium in a second chamber of the three-chamber configuration, which results in the saltwater in the first chamber to be conveyed into the membrane module at the high pressure necessary for reverse osmosis. Simultaneously, the concentrated salt water, which has not penetrated through the membrane of the membrane module, is conveyed into a third chamber of the three-chamber configuration. Finally, the next delivery of salt water by the first pump into the first chamber results in the concentrated salt water being discharged from the third chamber, and ultimately from the device.

In this known method the high-pressure pump delivers a pressure medium at a high pressure level to the membrane modules, and no longer has to pump salt water, as has been the case in other known methods, and which due to the salt water's oxidation potential exacted high demands on the material of the pump, which significantly increased its costs. But a high-pressure pump to create the pressure necessary for reverse osmosis is still required, which has a negative effect on the energy balance, and consequently on the overall efficiency of the device. In addition, the known method operates in two processing steps, whereby one of the two processing steps generates desalted water, while the other processing step re-supplies salt water and discharges the concentrated salt water.

BRIEF SUMMARY OF THE INVENTION

The object of the invention is to provide a method with improved efficiency and a device for the implementation of desalting water.

The invention is based on the realization that a pump to generate the high pressure necessary for reverse osmosis can be omitted entirely and be replaced by a pump generating a significantly lower pressure, if the pressure, which the concentrated salt water inevitable possesses at the outlet of the membrane module, can be utilized by continuously re-circulating this concentrated salt water into the pressure-compensating device to pressurize the salt water pumped into the pressure-compensating device. In this context it is particularly beneficial that this process takes place continuously, since otherwise the pressure in the salt water feed pipe from the pressure-compensating device to the membrane module would drop and would have to be re-generated by a high-pressure pump, as is the case in the known method, and in addition no continuous production of desalted water would be possible.

Advantageous further developments of the method and the device follow from the dependent claims.

The invention is explained in more detail in the following with the help of the figures.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

Figure 1 shows a schematic diagram illustrating the method according to the invention,

Figure 2 shows an embodiment of the device according to the invention,

Figures 3a and 3b show representations of this embodiment during different operating stages, and

Figure 4 is a representation of the operating stages of this embodiment during a complete operating cycle.

DETAILED DESCRIPTION OF THE INVENTION

The schematic diagram of Figure 1 shows a feed pump 1 to introduce salt water 10 into a pressure-compensating device 2 at a first pressure p_1. The same salt water 11, which now is pressurized to the high operating pressure necessary for reverse osmosis, is conveyed from the pressure-compensating device 2 to the membrane module 3. Here part of the salt water 11, due to the high pressure, penetrates though the membrane 6 (for example 25% of the salt water 11), is desalted in the process, and is discharged as desalted water 12. The remaining portion of the salt water 11 (*e.g.*, 75%) cannot penetrate through the membrane 6, and is returned as concentrated salt water 13, still at the high pressure level p_2, to the pressure-compensating device 2 through a connecting line 5. There, this high pressure level is used, in a manner still to be

explained in more detail, to pressurize the salt water 10 introduced into the pressure-compensating device 2 to a high pressure level and to convey it to the intake of the membrane module 3. Simultaneously, also in a manner still to be explained in more detail, the pressure level p_1, to which the salt water 10 is pressurized by the feed pump 1, is used in the pressure-compensating device 2 to ultimately discharge any concentrated salt water 14 present therein through the discharge line 4. All of the described stages take place simultaneously and continuously, so that no high-pressure pump is required to re-generate a high operating pressure, and desalted water 12 is available continuously.

In particular the design and operating principle of the pressure-compensating device 2 will be explained in more detail with help of the invention's embodiment shown in Figure 2. Here, the pressure-compensating device possesses three identical piston devices 20, 30, 40, each of which possesses one intake chamber 21, 31, 41 to take in the salt water 10, one discharge chamber 22, 32, 42 to accept the concentrated salt water 13, and one pressure chamber 23, 33, 43.

Each of the piston devices 20, 30, 40 contains a special piston 24, 34, 44, which subdivides the piston interior into the mentioned chambers, and which in the drawing can move in the vertical direction within the piston arrangement. Feed pipes with (passive) check valves 28, 38, 48 lead from the feed pump 1 to each of the intake chambers 21, 31, 41. Hereby, the design of the check valves 28, 38, 48 is such that they open to admit flow if the pressure level in the feed pipe is higher than that in the intake chambers 21, 31, 41. The feed pipes from the intake chambers 21, 31, 41 to the membrane module 3 also contain check valves 27, 37, 47 of this type, but with a different flow direction. In contrast, the feed pipe 5 from the membrane module to the discharge chambers 22, 32, 42, and the discharge line 4 from the discharge chambers 22, 32, 42, are provided with actively controlled valves 25, 35, 45, and 26, 36, 46, respectively, which may be used to regulate the inflow of concentrated salt water 13 from the membrane module 3, or the outflow of the concentrated salt water 14 from the pressure-compensating device 2. The pressure chambers 23, 33, 43 are connected to each other by a connecting line 7, in order to enable pressure compensation between these three chambers and to ensure an identical pressure level p_3 in all three chambers.

The following illustrates the operating principle of the device: The feed pump 1 pumps 100% of the required volume of salt water 10 at a first pressure p_1 level (*e.g.,* 17.5 bar) into the intake chamber 31, whereby the check valve 38 opens, which is indicated by the arrow next to it. At this time the valve 36 is open (indicated by the arrow next to it), so that the concentrated salt water 14 present in the discharge chamber

32 can be discharged through the discharge line 4. As a result of the salt water 10 flowing into the intake chamber 31 at a pressure level p_1, the piston 34 is subjected to a force $F = p_1 \bullet A$, where A is the surface area of the piston face 341. As a result, the piston 34 is pushed upward, as indicated in the figure, and the concentrated salt water present in the discharge chamber 32 is discharged through the valve 36 and the discharge line 4. The pressure level p_3 prevailing in the pressure chamber 33 gives rise to an opposing force $FG = p_3 \bullet A_G$ (A_G is the surface area of the part 343 of the rear of the piston, *e.g.*, a quarter of the piston's rear side), which is nearly as large, or slightly smaller than the force F. During the same shown operating stage, the valve 25 is open, so that the concentrated salt water 13 flows from the membrane module 3 into the discharge chamber 22 at the pressure level p_2 (*e.g.*, 70 bar).

Simultaneously, in the pressure chamber 23, which has been filled by the pressure medium through the connecting line 7 due to the upward travel of the piston 34, a force is exerted on the piston 24, causing it to travel downward, as indicated by the arrow. This causes the salt water 11 to be conveyed from the intake chamber 21 through the open check valve 27 to the membrane module 3. Inevitably, this takes place at the pressure level p_2 (70 bar), since the discharge chamber 22 and the pressure chamber 23 are subjected to a pressure of that level. All other valves are closed during the shown operating stage.

Consequently, the shown embodiment of the pressure-compensating device 2 achieves a pressure transformation, which allows a highly efficient energy recovery from the concentrated salt water 13 being discharged. For this reason, instead of a high-pressure pump to generate the high operating pressure necessary for reverse osmosis one only requires a low-power filling pump 1, which in this particular case only has to generate a pressure level that is one quarter of the working pressure.

Figures 3a and 3b show six different successive operating stages of the device according to the invention. Hereby the arrows 201, 202, 301, 302 are meant to indicate an open valve and the direction of the flow. The arrows 203, 303, and the zero 403 are meant to show whether the piston of the respective piston device 20, 30, 40 is moving, and if so, the direction of its travel. Position sensors 204, 205, 304, 305 to detect the piston position are provided at each of the upper and lower ends of the pressure chambers 23, 33, 43 of the piston devices 20, 30, 40. The left-hand diagram of each of the stage diagrams shows the valve position and piston travel direction that were in effect to reach the shown piston position. The right-hand diagram of each stage diagram then shows how from this point in time the pistons will move as a result of the changed valve settings. For example, the left-hand diagram of the representation of

stage 1 shows that up to that moment the piston 24 has been traveling downward to the limit stop (arrow 203), that the piston 34 is in the process of traveling upwards (arrow 303), and that the piston 44 was remaining at an upper limit position (zero 403). After switching the valves - valve 25 has been closed and valve 45 has been opened; valve 27 closes whereupon valve 47 opens automatically - the piston 24 remains in its lower limit position, as shown in the right-hand diagram of the representation of stage 1, while the piston 34 continues to travel upward and the piston 44 is traveling downward. The last stage 6 is again followed by stage 1.

The following table illustrates the valve settings in the six shown stages, whereby '+' represents an open valve and '-' represents a closed valve.

Stage / Valve	1	2	3	4	5	6
25	+	-	-	-	-	+
26	-	-	+	+	-	-
35	-	-	-	+	+	-
36	+	+	-	-	-	-
45	-	+	+	-	-	-
46	-	-	-	-	+	+
27	+	-	-	-	-	+
28	-	-	+	+	-	-
37	-	-	-	+	+	-
38	+	+	-	-	-	-
47	-	+	+	-	-	-
48	-	-	-	-	+	+

Finally, Figure 4 shows the operating states, *i.e.,* the piston positions over the course of a complete operating cycle, which here has been subdivided into twelve individual stages. Once again, the direction of the arrow represents the direction of travel of the respective piston. In one embodiment, this process takes place continuously.

The invention is not restricted to the shown embodiment; in particular the pressure-compensating device can be of a different design. Alternative designs are possible, for example configurations with only two piston devices, or more than three piston devices, and/or piston devices that are of different designs or are different from each other. Furthermore, the specified numerical values are only examples used to

illustrate the invention, *i.e.,* a modified piston geometry can result in different pressure ratios, for example.

The method and device according to the invention make it possible to achieve a very high energy-recovery efficiency of at least 90%. The feed pump only has to generate approximately a quarter of the working pressure of approximately 70 bar necessary for reverse osmosis, which entails significant cost-reduction- and service benefits. Consequently, the invention significantly reduces the general manufacturing costs of a device to desalt water and provide drinking water. The specified pressure ratio (17.5 bar: 70 bar) can be fixed at a different ratio. This can be accomplished by modifying the piston geometry. The piston geometry is not limited to a single possible configuration. Depending on the salt content of the water, the osmotic pressure can and should be adapted. A lower pressure can be selected for brackish water, which has the lowest salt content; in this case the ratio may be changed or adjusted from 1/4: 3/4 to 1/3: 2/3.

The pressure in the pressure chambers 23, 33, 43 is established during start-up of the device and subsequently is kept constant at that level.

From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.

CLAIMS

1. A method for desalting water, comprising:

salt water is introduced into a membrane module and is separated into desalted water and concentrated salt water;

the salt water is conveyed at an increased pressure level from the pressure-compensating device, which comprises several piston devices, to the membrane module;

the concentrated salt water is discharged from the pressure-compensating device, transferring its pressure energy in the process;

salt water is introduced into the pressure-compensating device at a pressure level by means of a feed pump;

in front of the piston, the piston devices contain an intake chamber, which is connected to the feed pump and the membrane module, and in the rear of the piston they contain a discharge chamber, which is connected to the membrane module and a discharge line for concentrated salt water; and

during operation a pressure is exerted on a part of the piston by means of a hydraulic connection between the pressure chambers, which are located at the piston rear sides of the piston devices, to assist the pressure level, which is exerted on the piston by the concentrated salt water that has been introduced into the discharge chambers.

2. The method according to claim 1, wherein concentrated salt water alternately is introduced into the discharge chamber of one of several piston devices, whereby simultaneously the salt water conveyed from the intake chamber of the same piston device to the membrane module, and in that simultaneously salt water at a first pressure level is introduced into the intake chamber of a different piston device, whereby the concentrated salt water is discharged at a low pressure level from the discharge chamber of the same piston device.

3. The method according to claim 2, wherein the piston devices of the pressure-compensating device are controlled in such a manner that simultaneously salt water is introduced into the intake chamber of at least one of the piston devices, concentrated salt water is discharged from the discharge chamber of the same piston device, concentrated salt water is introduced into the discharge chamber of at least one

other piston device, and salt water is conveyed from the intake chamber of the same piston device into the membrane device.

4. The method according to claim 1, characterized in that the piston devices are regulated by controllable intake- and discharge valves.

5. The method according to claim 1, wherein the pressure exerted on a part of the piston is a continuous pressure.

6. A reverse osmosis device for the continuous desalting of water, in particular for the desalting of sea water, comprising:

a membrane module to separate supplied salt water into desalted water and concentrated salt water;

a pressure-compensating device, comprising several piston devices, to continuously introduce the salt water at an increased pressure level into the membrane module and to discharge the concentrated salt water, transferring its pressure energy in the process,

a feed pump to introduce salt water at a pressure level into the pressure-compensating device, whereby

in front of the piston, the piston devices possess an intake chamber, which is connected to the feed pump and the membrane module, and

in the rear of the piston, the piston devices possess a discharge chamber, which is connected to the membrane module and to a discharge line for concentrated salt water,

in the rear of the piston, the piston devices additionally possess a pressure chamber and the pressure chambers are hydraulically connected to each other, so that during operation a continuous pressure can be exerted on a part of the piston to assist the pressure, which is exerted on the piston by the concentrated salt water introduced into the discharge chamber.

7. The device according to claim 5, wherein the piston devices are controlled in such a manner that simultaneously salt water is introduced into the intake chamber of at least one piston device, concentrated salt water is discharged from the discharge chamber of the same piston device, concentrated salt water is introduced into the discharge chamber of at least one other piston device, and salt water is conveyed from the intake chamber of the same piston device to the membrane module.

8. The device according to claim 6, wherein the piston devices are regulated by controllable intake- and discharge valves.

9. The device according to claim 7, wherein the connecting lines from the membrane module to the discharge chambers of the piston devices, and the lines to discharge concentrated salt water from the discharge chambers are provided with actively controlled valves.

10. The device according to one of claim 5, wherein the pressure-compensating device contains three identical piston devices.

11. The device according to one of claim 5, wherein the pistons of the piston devices are designed in such a manner that the pressure level prevailing in the pressure chamber can act upon one quarter of the surface area of the piston rear side and the pressure level prevailing in the discharge chamber can act upon three quarters of the surface area of the piston rear side.

ABSTRACT OF THE DISCLOSURE

The invention concerns a method for desalting water by reverse osmosis, in particular for desalting sea water, whereby salt water at a first pressure level is introduced into a pressure compensating device, and is conveyed from the pressure-compensating device at a second, higher pressure level into a membrane module, whereby desalted water and concentrated salt water are discharged from the membrane module. In order to increase the efficiency and consequently the energy balance of such a method, the invention proposes to continuously introduce the concentrated salt water, which has been discharged from the membrane module, at a second pressure level into the pressure-compensating device, wherein it is used to subject the salt water introduced into the pressure compensating device to the second pressure level, and to discharge the salt water and convey it to the membrane module. The invention also concerns a device for implementing this method.

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PTO/SB/01 (10-01) (modified)

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)	Attorney Docket No.	970054.412USPC
	First Named Inventor	Aloys Wobben
	COMPLETE IF KNOWN	
	Application Number	10/031,840
	Filing Date	
[ ] Declaration Submitted with Initial Filing [X] Declaration Submitted after Initial Filing	Group Art Unit	Not yet known
	Examiner's Name	Not yet known

As the below named inventor(s), I/we hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I/we believe that I/we am/are the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD AND DEVICE FOR DESALTING WATER

(Title of Invention)

the specification of which was filed on (MM/DD/YYYY) **March 18, 2000** — the specification of which is attached hereto [ ]

as United States Application Number or PCT International Application Number **PCT/EP00/02417** — Express Mail No. [ ]

and was amended on (MM/DD/YYYY) *(if applicable)* [ ]

I/we have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

In addition, I/we acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me/us to be material to patentability as defined in 37 CFR 1.56, including material information which became available between the filing date of the prior application and the National or PCT International filing date of the continuation-in-part application, if applicable.

I/we hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Claimed	Certified Copy Attached? YES	NO
19933147.2	DE	July 20, 1999	Y		X
PCT/EP00/02417	WO	March 18, 2000	Y		X

Additional foreign application numbers are not listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

I/we hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application No.	Filing Date (MM/DD/YYYY)	Application No.	Filing Date (MM/DD/YY)

Additional provisional application numbers are not listed on a supplemental priority data sheet PTO/SB/02B attached hereto

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I/we hereby declare that all statements made herein of my/our own knowledge are true and that all statements made herein on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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